Pimp my Java

Daniel Petisme
Philippe Charrière

Us?

@k33g_org

aka. Golo Developer Advocate

@danielpetisme

invokedynamic?

Java VM

~~Java VM~~

Multi-Language VM

The Java SE 7 platform enables ***non-Java languages*** *to exploit the infrastructure and potential performance optimizations of the JVM.*

The key mechanism is the ***`invokedynamic`*** *instruction, which* ***simplifies the implementation*** *of compilers and runtime systems for* ***dynamically typed languages*** *on the JVM.*

http://docs.oracle.com/javase/7/docs/technotes/guides/vm/multiple-language-support.html

Static

```
public class Adder {

  public Integer add(Integer a, Integer b ) {
    return a + b;
  }

  public String add(String a, String b ) {
    return a + b;
  }

  public static void main(String[] args) {
    Adder myAdder = new Adder();
    int x = 10;
    int y = 10;

    List<String> jugs = new ArrayList<>();
    String theBestOne = "LavaJUG";

    jugs.add(theBestOne);
    myAdder.add(x, y);

    myAdder.add("The Best JUG is: ",theBestOne);

  }
}
```

Types checking at compilation...

Dynamic

```
class Adder {

  def add(a, b) {
    return a + b
  }

  def main(args) {
    def myAdder = new Adder()
    def x = 10
    def y = 10

    def jugs = []
    def theBestOne = "LavaJUG";
    jugs.add(theBestOne)

    myAdder.add(x, y)
    myAdder.add("The Best JUG is: ",
theBestOne)

  }
}
```

Types checking at runtime...

And what’s the problem?

Dynamic language compilation

```java
public class Adder {

  public Integer add(Integer a, Integer b ) {
    return a + b;
  }

  public String add(String a, String b ) {
    return a + b;
  }

  public static void main(String[] args) {
    Adder myAdder = new Adder();
    int x = 10;
    int y = 10;

    List<String> jugs = new ArrayList<>();
    String theBestOne = "LavaJUG";

    jugs.add(theBestOne);
    myAdder.add(x, y);

    myAdder.add("The Best JUG is: ",theBestOne);

  }
}
```

KEEP
CALM
AND
COMPILE
PLEASE

```
public static void main(java.lang.String[]);
  flags: ACC_PUBLIC, ACC_STATIC
  Code:
    stack=3, locals=6, args_size=1
       0: new           #8          // class lavajug/sample1/Adder
       3: dup
       4: invokespecial #9          // Method"<init>":()V
       7: astore_1
       8: bipush        10
      10: istore_2
      11: bipush        10
      13: istore_3
      14: new           #10         // class java/util/ArrayList
      17: dup
      18: invokespecial #11         // Methodjava/util/ArrayList."<init>":()V
      21: astore        4
      23: ldc           #12         // String LavaJUG
      25: astore        5
      27: aload         4
      29: aload         5
      31: invokeinterface #13,  2   // InterfaceMethodjava/util/List.add:(Ljava/lang/Object;)Z
      36: pop
      37: aload_1
      38: iload_2
      39: invokestatic  #3          // Methodjava/lang/Integer.valueOf:(I)Ljava/lang/Integer;
      42: iload_3
      43: invokestatic  #3          // Methodjava/lang/Integer.valueOf:(I)Ljava/lang/Integer;
      46: invokevirtual #14         // Methodadd:(Ljava/lang/Integer;Ljava/lang/Integer;)Ljava/lang/Integer;
      49: pop
      50: aload_1
      51: ldc           #15         // String The Best JUG is:
      53: aload         5
      55: invokevirtual #16         // Methodadd:(Ljava/lang/String;Ljava/lang/String;)Ljava/lang/String;
      58: pop
      59: return
```

1- Types present at the callsites


```
public static void main(java.lang.String[]);
  flags: ACC_PUBLIC, ACC_STATIC
  Code:
    stack=3, locals=6, args_size=1
       0: new           #8          // class lavajug/sample1/Adder
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```

1- Types present at the callsites

2- Method must exist at compile time


```
public static void main(java.lang.String[]);
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  Code:
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      58: pop
      59: return
```

1- Types present at the callsites

2- Method must exist at compile time

3- No relinking possible


```
public static void main(java.lang.String[]);
  flags: ACC_PUBLIC, ACC_STATIC
  Code:
    stack=3, locals=6, args_size=1
       0: new           #8          // class lavajug/sample1/Adder
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      53: aload         5
      55: invokevirtual #16         // Methodadd:(Ljava/lang/String;Ljava/lang/String;)Ljava/lang/String;
      58: pop
      59: return
```

How to invoke

invokeStatic

```
Integer.valueOf(10);
```

```
invokestatic #3 // Method java/lang/Integer.valueOf:(I)Ljava/lang/Integer;
```

invokeSpecial

```
new ArrayList();
```

```
invokespecial #11 // Method java/util/ArrayList."<init>":()V
```

invokeInterface

```
jugs.add(theBestOne);
```

```
invokeinterface #13,  2 // InterfaceMethod java/util/List.add:(Ljava/lang/Object;)Z
```

invokeVirtual

```
myAdder.add("The Best JUG is: ",theBestOne);
```

```
invokevirtual #16 // Method lavajug/sample1/java/Adder.add:(Ljava/lang/String;
Ljava/lang/String;)Ljava/lang/String;
```

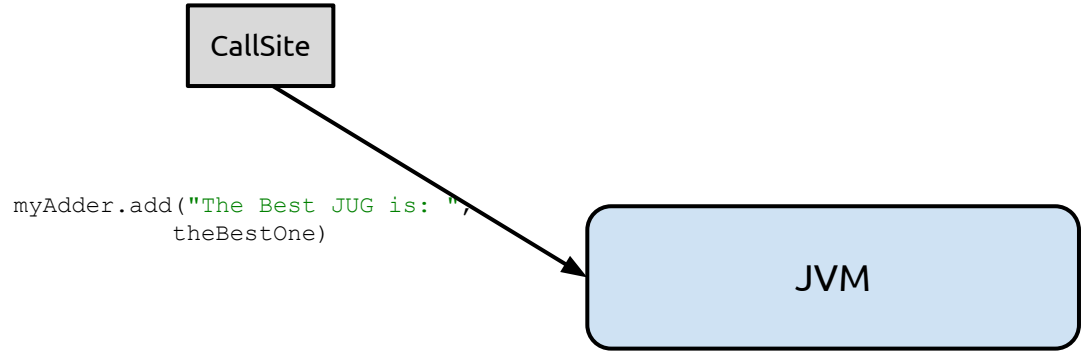
CallSite

Receiver	ReceiverClass	Name	Descriptor
myAdder	**Adder**	add	(Ljava/lang/String;Ljava/lang/String;)Ljava/lang/String;

CallSite

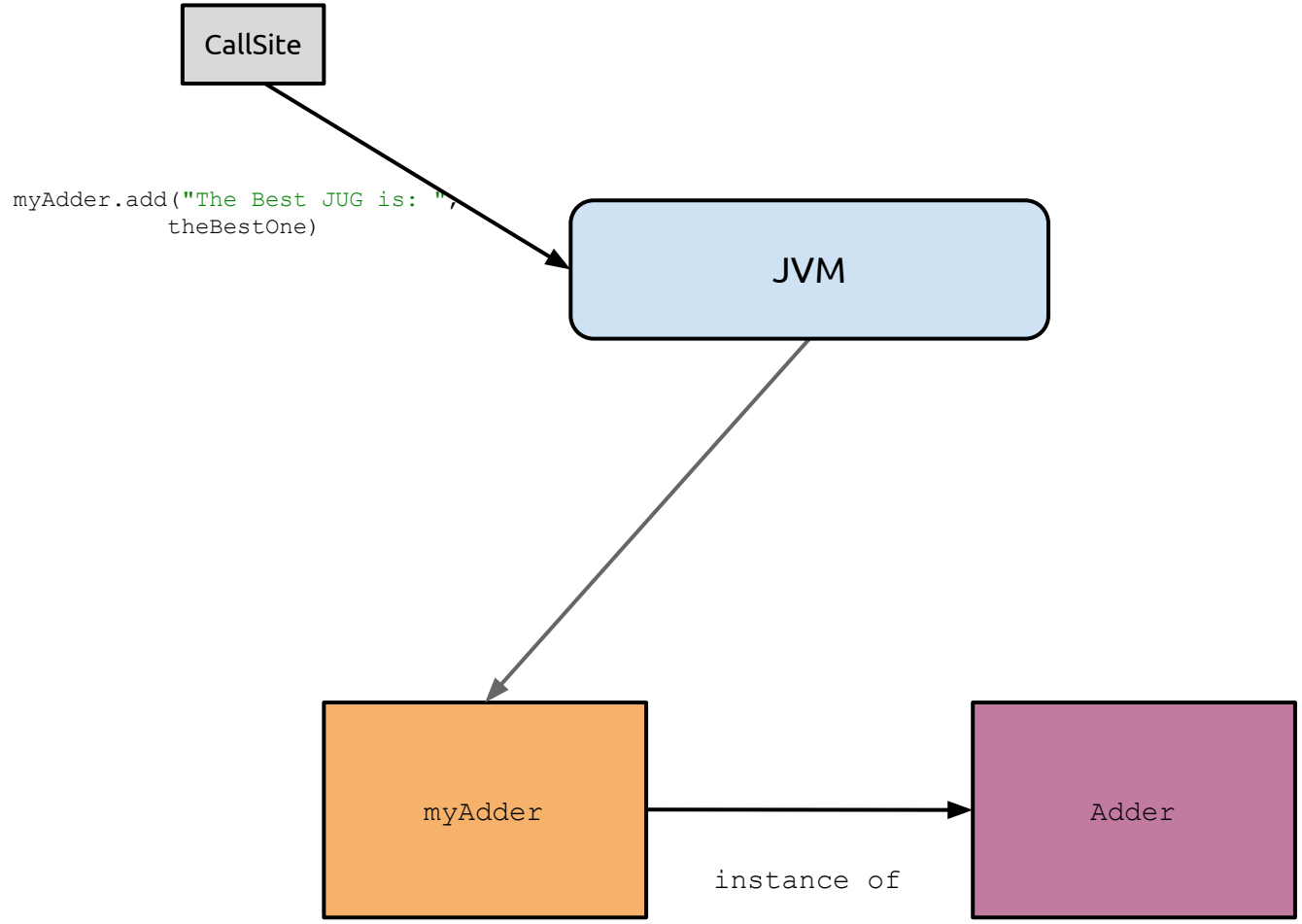
CallSite

Receiver	ReceiverClass	Name	Descriptor
myAdder	**Adder**	add	(Ljava/lang/String;Ljava/lang/String;)Ljava/lang/String;



CallSite

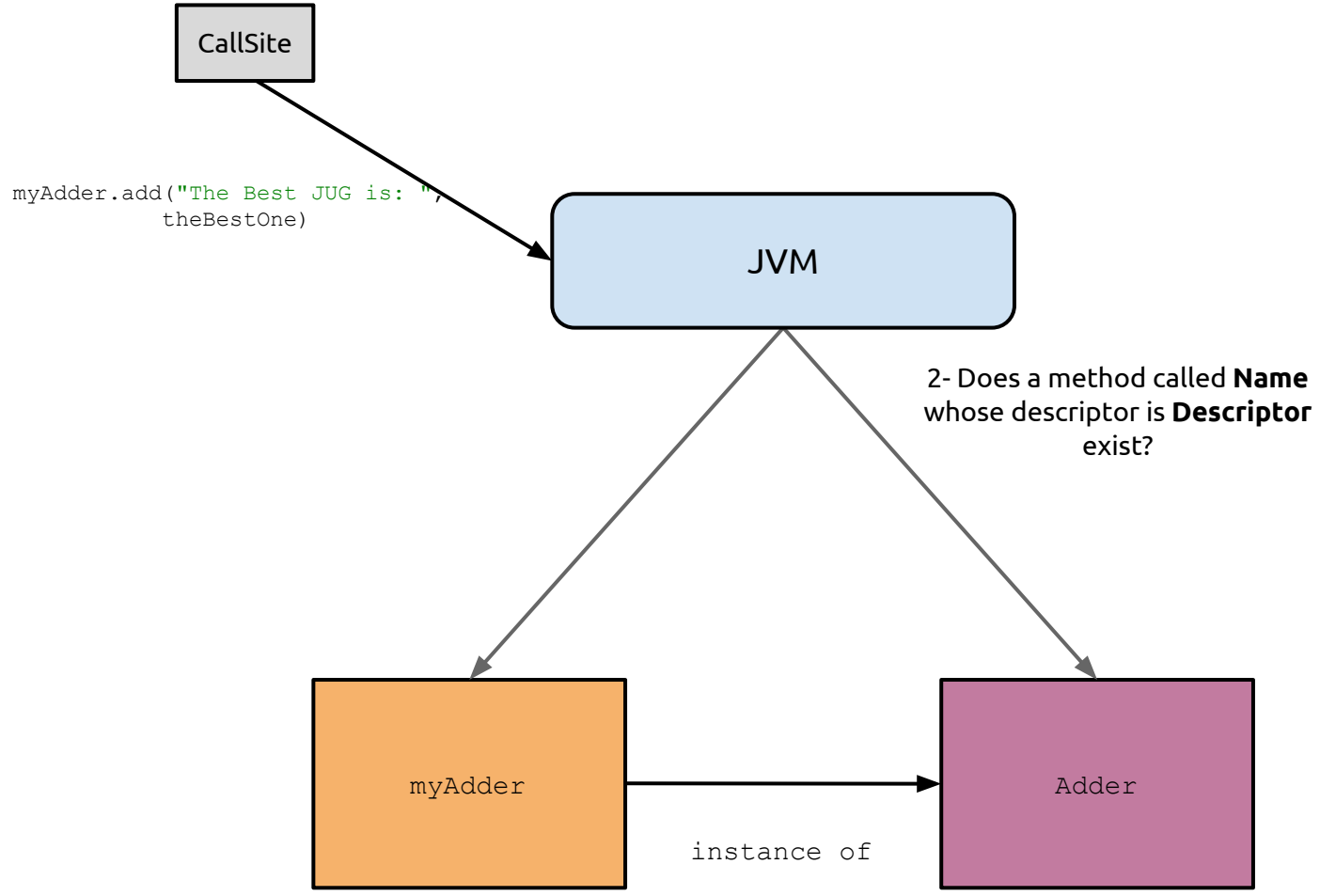
Receiver	ReceiverClass	Name	Descriptor
myAdder	**Adder**	add	(Ljava/lang/String;Ljava/lang/String;) Ljava/lang/String;



1- Is **Receiver** an instance of **ReceiverClass?**

CallSite

Receiver	ReceiverClass	Name	Descriptor
myAdder	**Adder**	add	(Ljava/lang/String;Ljava/lang/String;) Ljava/lang/String;



1- Is **Receiver** an instance of **ReceiverClass?**

CallSite

Receiver	ReceiverClass	Name	Descriptor
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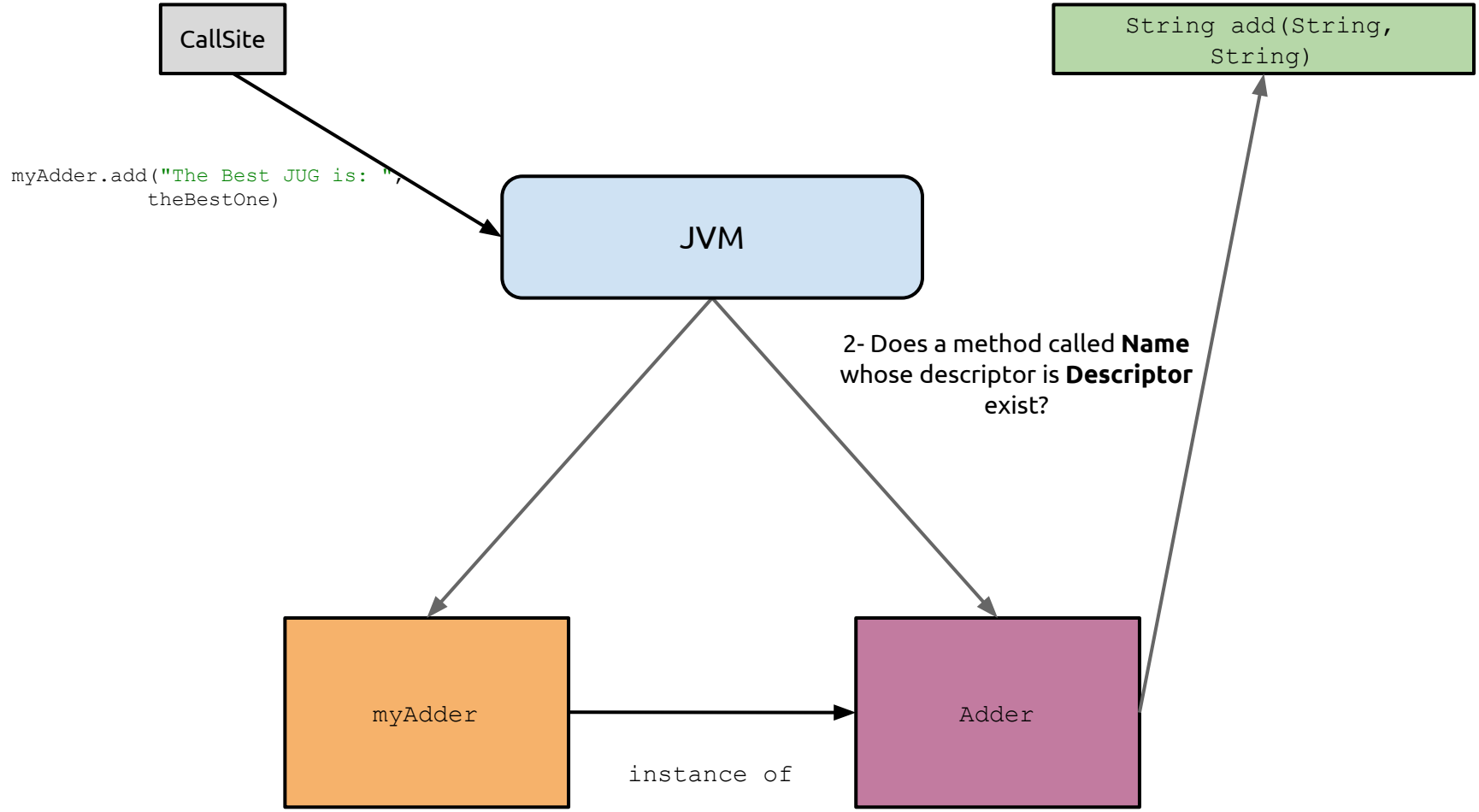
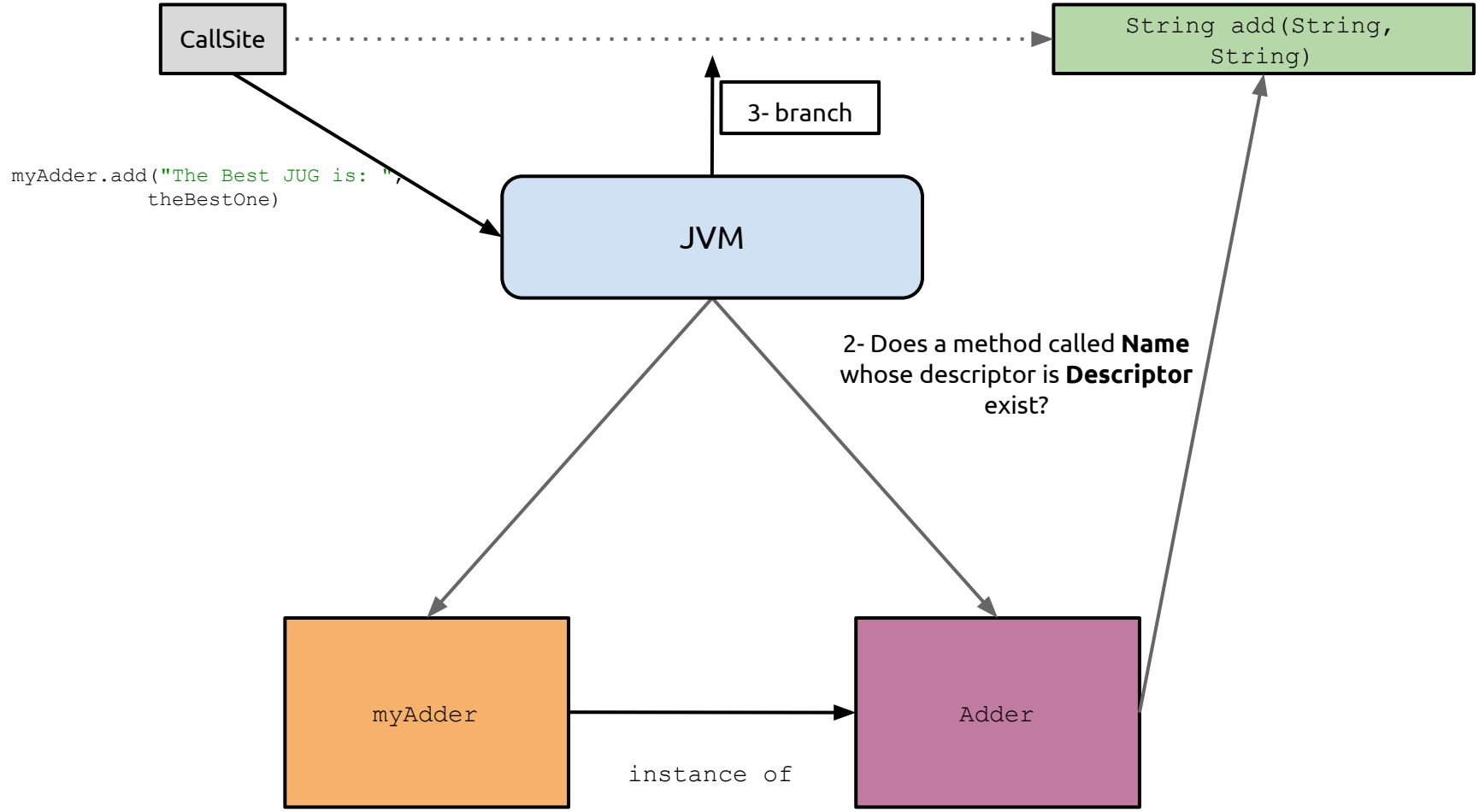


1- Is **Receiver** an instance of **ReceiverClass?**

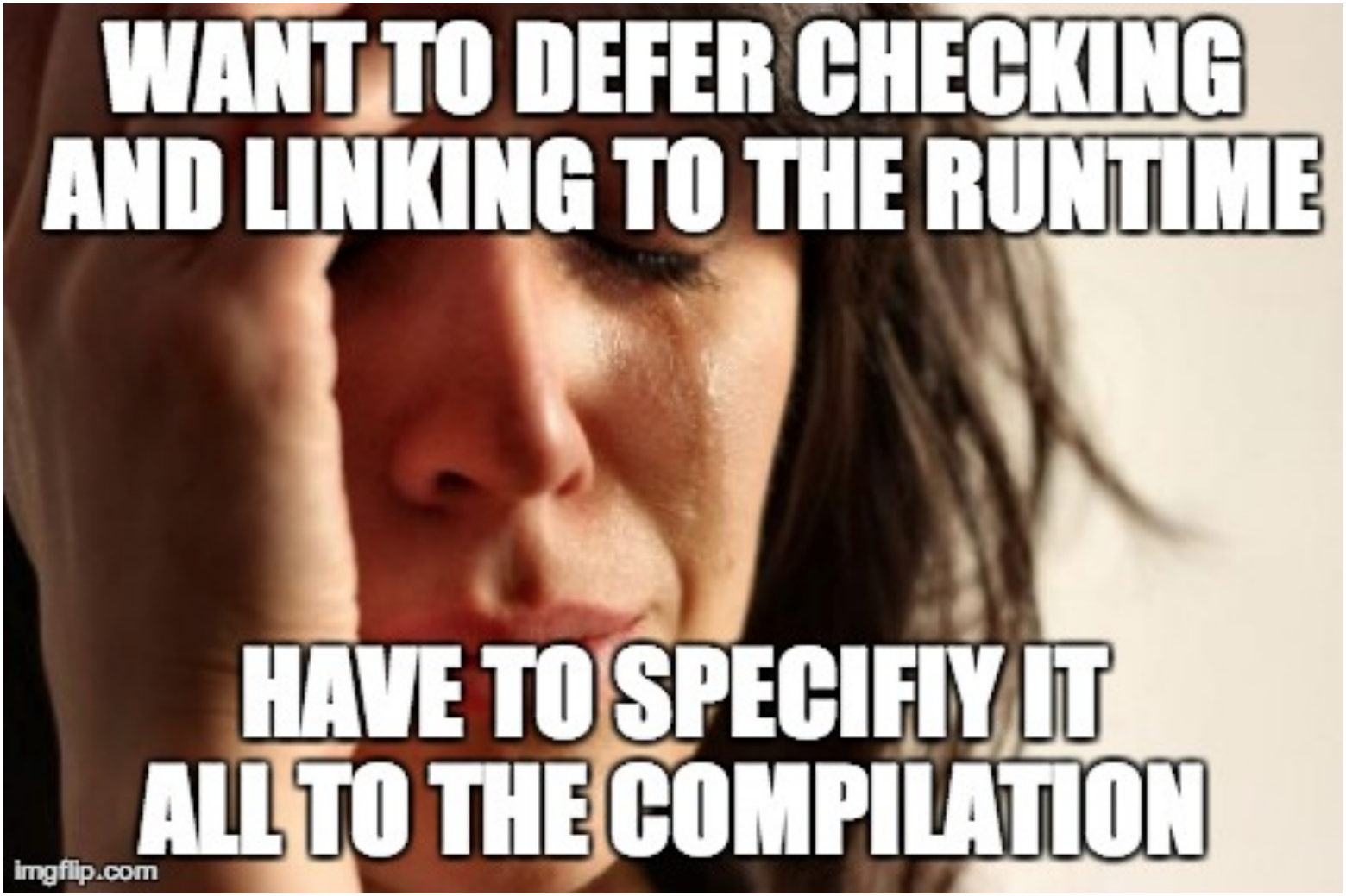
CallSite

Receiver	ReceiverClass	Name	Descriptor
myAdder	**Adder**	add	(Ljava/lang/String;Ljava/lang/String;) Ljava/lang/String;



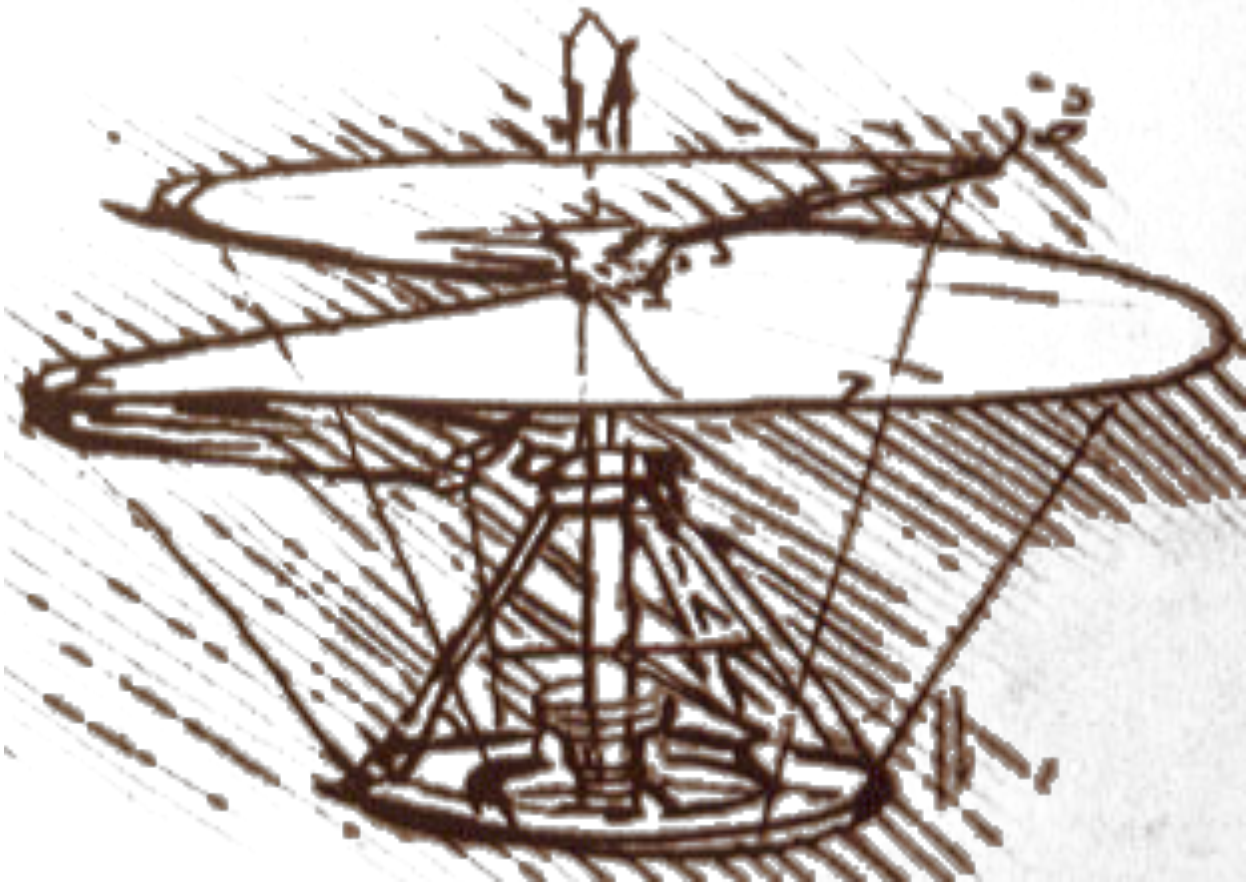
1- Is **Receiver** an instance of **ReceiverClass?**

Dynamic languages



invokedynamic!

JSR-292: Da Vinci Machine



New bytecode: `invokedynamic`

A new `invokedynamic` bytecode, that's all?

invokedynamic

Use symbolic specifications at compilation
Defer callsite bindings to runtime

invoke dynamic

user-defined bytecode

method linking & adaptation

Bonus: JVM Optimizations

New!

java.lang.invoke

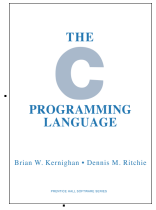
Chapter I
Method Handles

Method Handles?

Method Handles

≈

```
int (*functionPtr)(int,int);
```



```
String word = "Java";

MethodHandles.Lookup lookup = MethodHandles.lookup();

Class receiverType = String.class;
Class returnType = char.class;
Class paramType = int.class;

MethodHandle charAtHandle = lookup.findVirtual(
        receiverType,
        "charAt",
        MethodType.methodType(returnType, paramType)
);

char charAt0 = (char) charAtHandle.invokeWithArguments(word, 0);

assert charAt0 == 'J';
```

MethodHandle Factory embeds method handle access restrictions

Seek for a public exposed Method

Where to look for the Method

What we are looking for

Descriptor

Invocation with the receiver instance and the parameter(s)

Method Handles Vs. Reflection?

Method Handles Vs. Reflection?

Better/Easier discovery mechanism

Faster + Combination facilities

Method Handles Vs. Reflection?

Better/Easier discovery mechanism

Method Handles
&
Reflection!

```java
Lookup lookup = MethodHandles.lookup();

Method formatMethod = MessageFormat.class.getMethod(
        "format",
        String.class,
        Object[].class
);

MethodHandle greeterHandle = lookup.unreflect(formatMethod);

assert greeterHandle.type() == methodType(
        String.class,
        String.class,
        Object[].class
);
```

From `java.lang.reflect` to `java.lang.invoke`

Looks fun?
You ain’t see nothing!

```java
Lookup lookup = MethodHandles.lookup();

Method formatMethod = MessageFormat. class.getMethod(
        "format", String.class, Object[].class );


MethodHandle greeterHandle = lookup. unreflect(formatMethod);

greeterHandle = greeterHandle.
        bindTo("Hello {0} {1}{2}").
        asCollector(Object[].class, 3);

//Arguments manipulation
greeterHandle = MethodHandles. insertArguments(
        greeterHandle,
        greeterHandle.type().parameterCount() -  1,
        "!"
);

//Combining
Method toUpperMethod = String. class.getMethod("toUpperCase");
MethodHandle toUpperHandle = lookup.unreflect(toUpperMethod);

greeterHandle = MethodHandles. filterReturnValue(greeterHandle,
toUpperHandle);

//Test
String greet = (String) greeterHandle.invokeWithArguments( "John", "Doe");
assert greet.equals("HELLO JOHN DOE!");
```

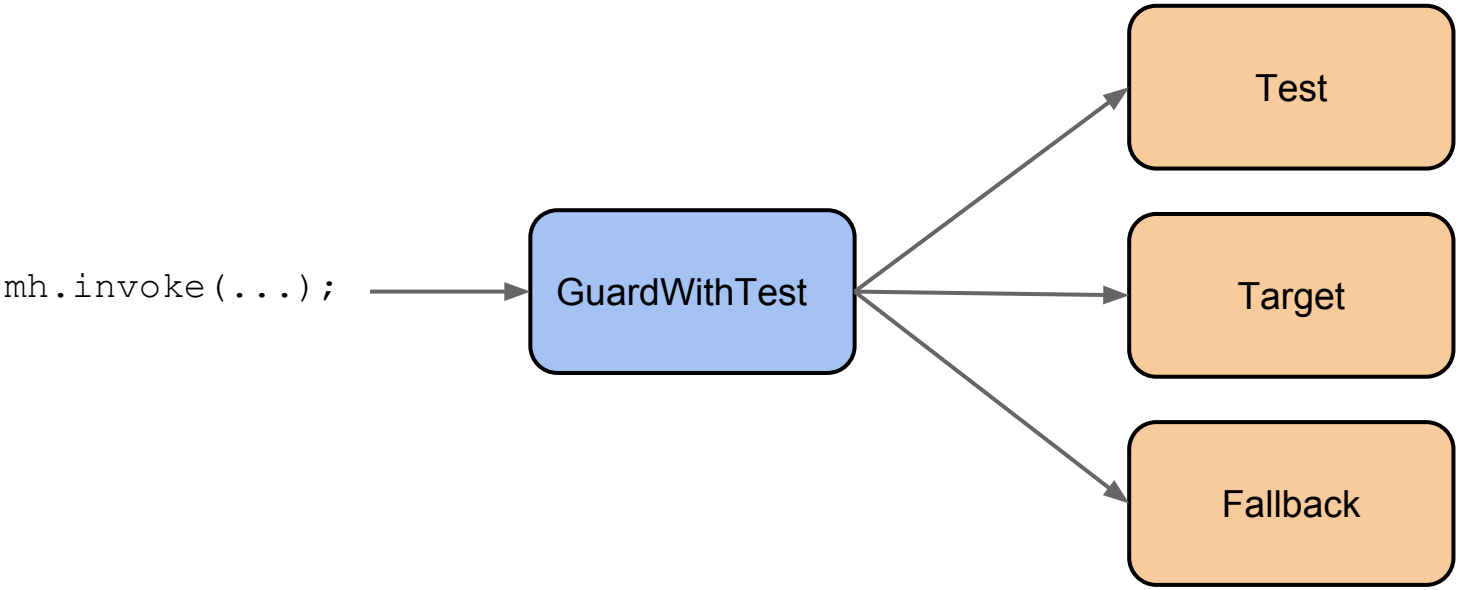
Curry power ❤

Now representing a 3 args method

Add/remove/move arguments

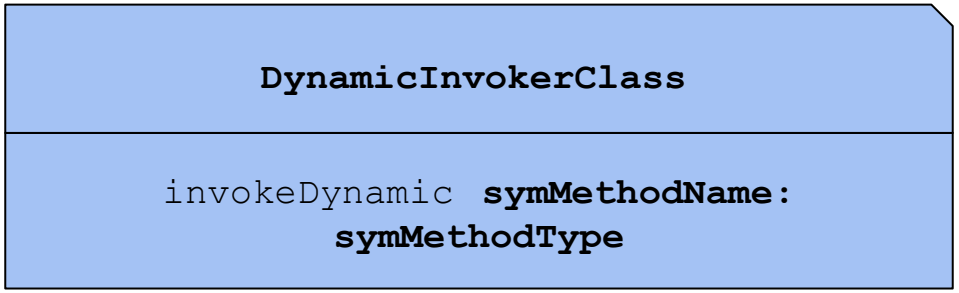
Split the concerns, then combine the methods


YOU SHALL NOT
PASS

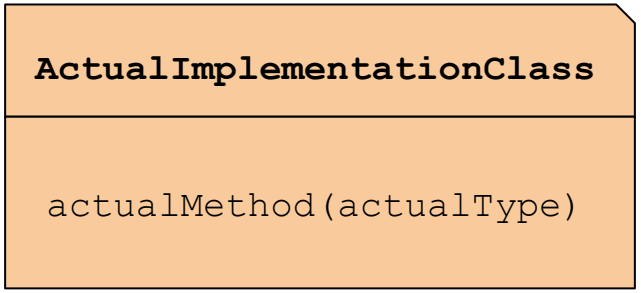

mh.invoke(...);
GuardWithTest
Test
Target
Fallback

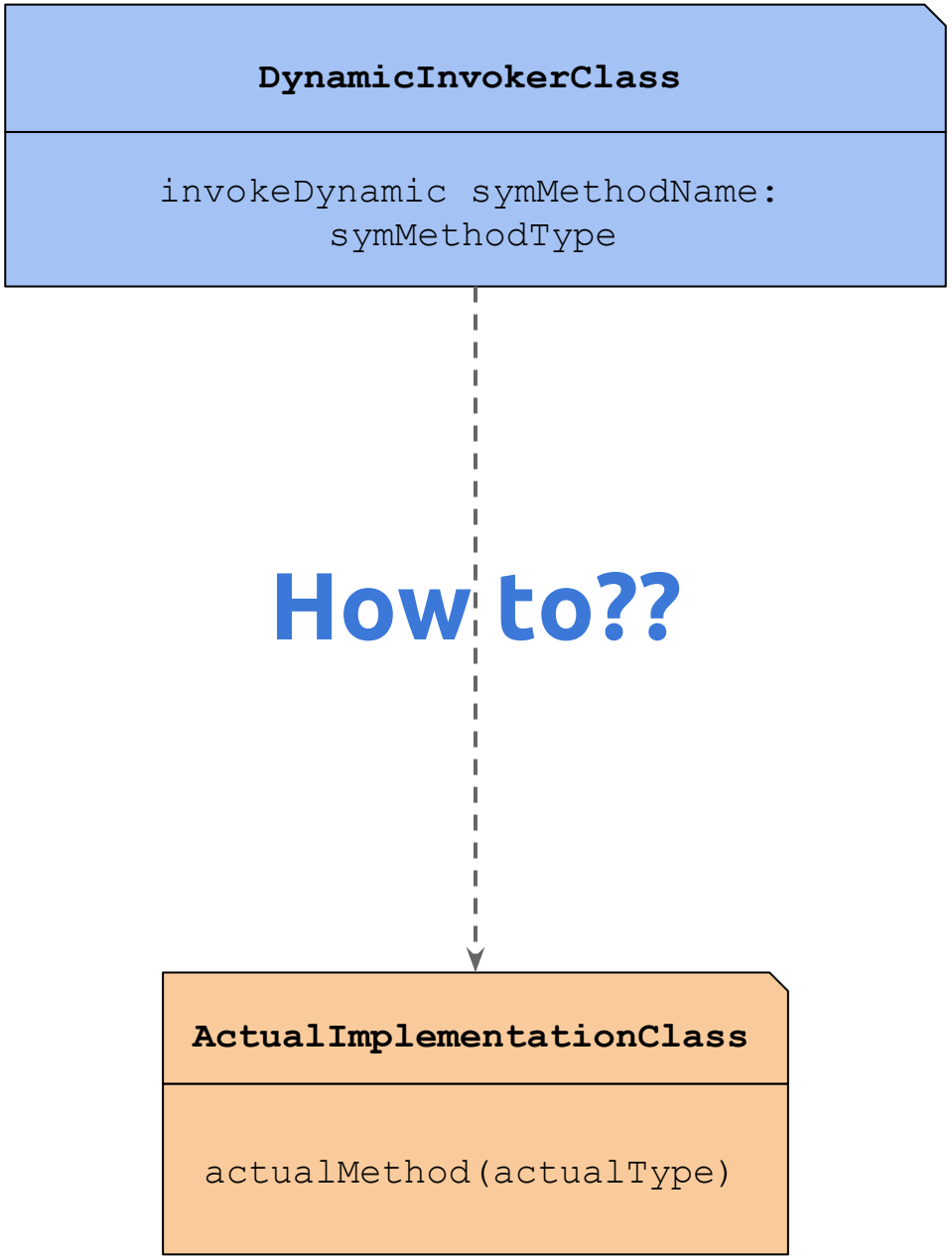
Get prepared for λ…

Chapter II
BootStrapping

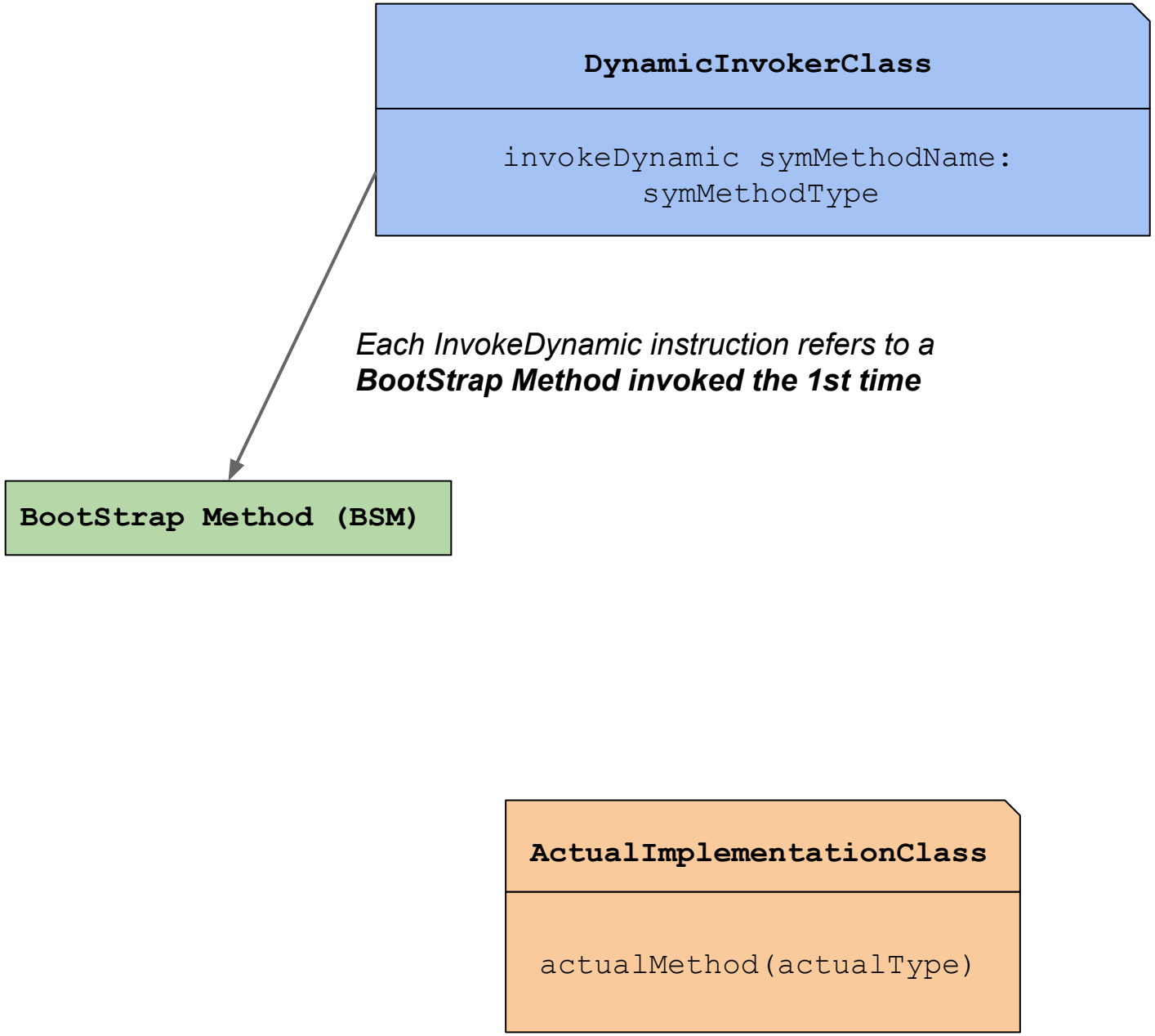


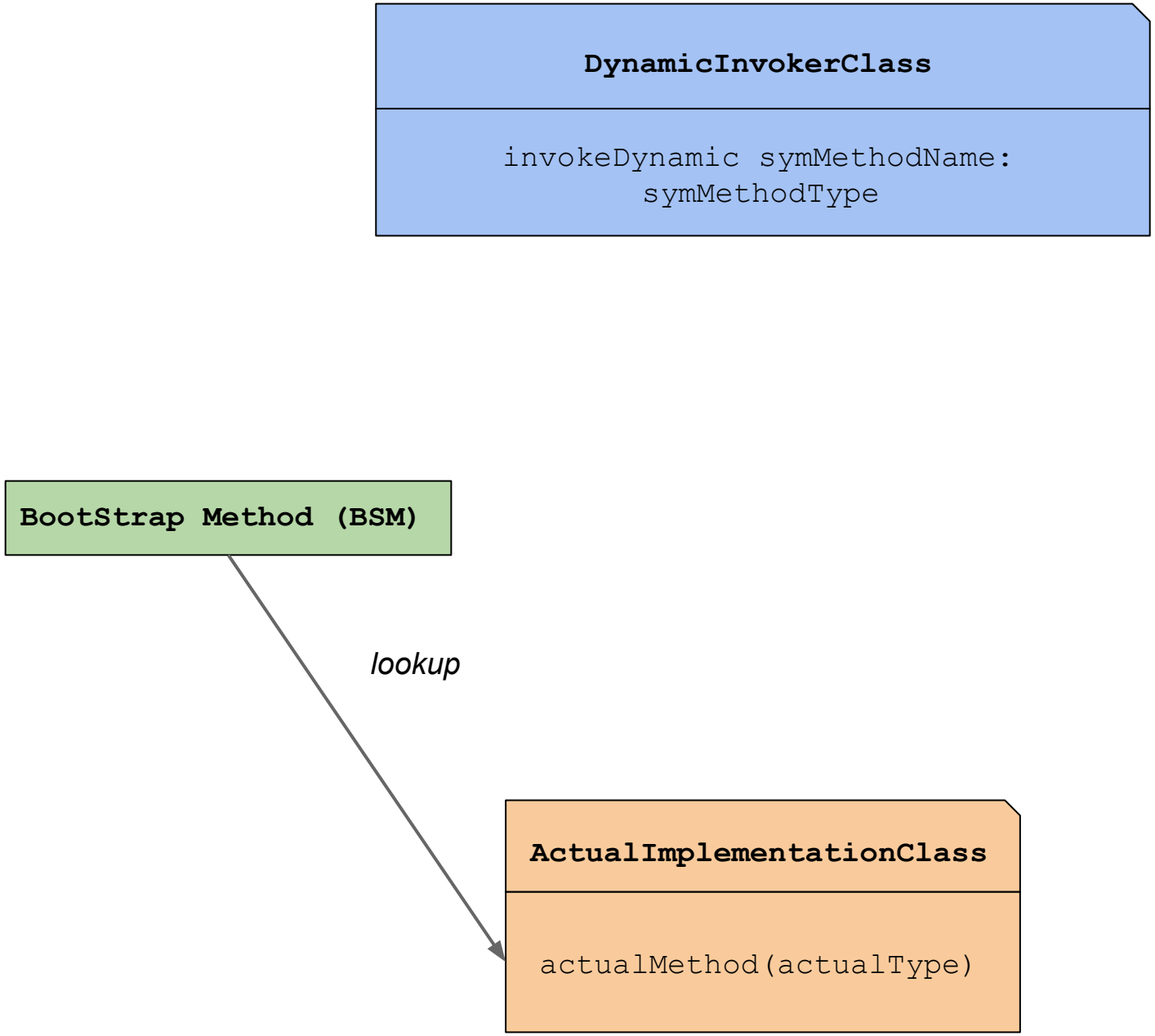
At compilation: Method pointers

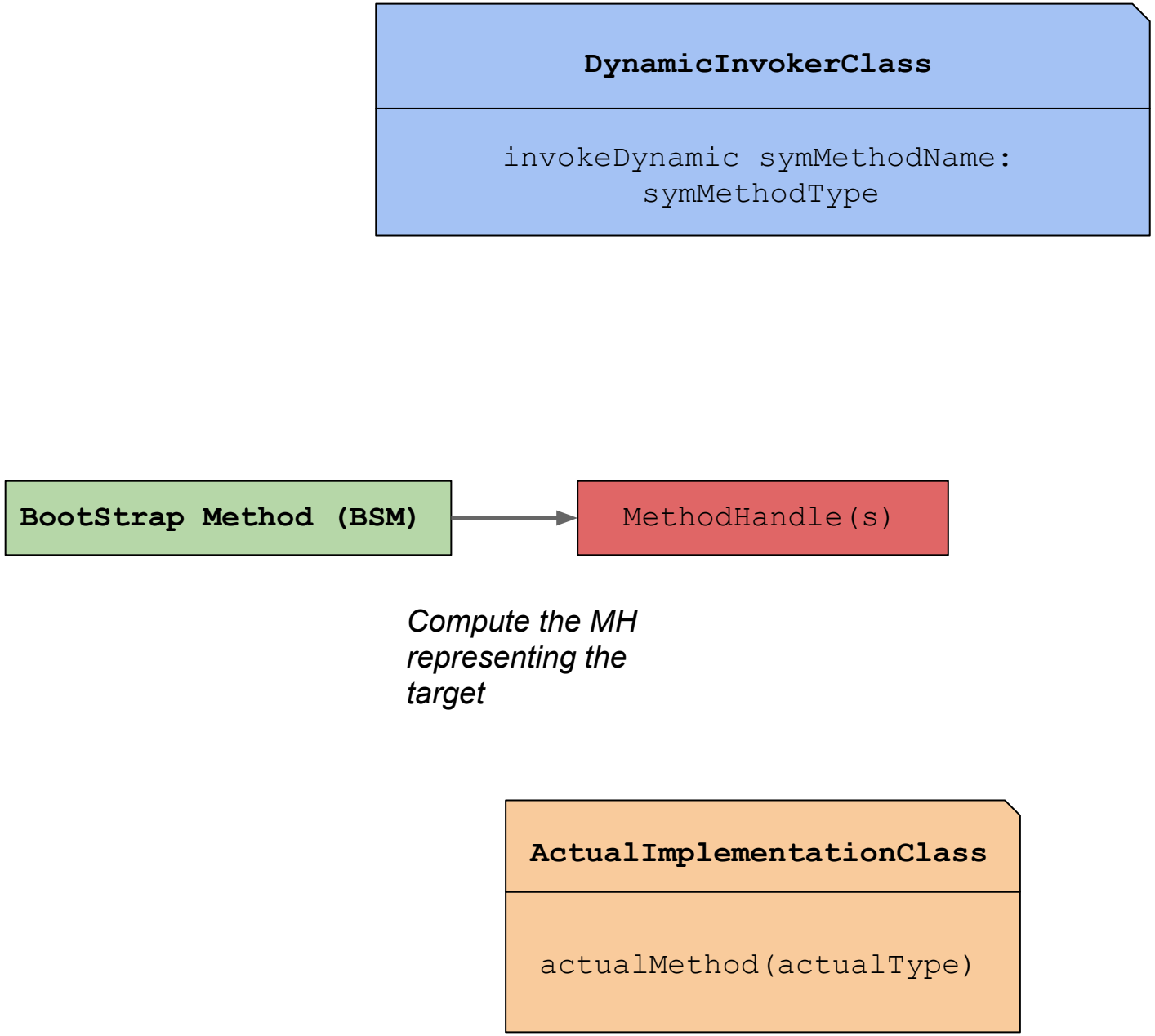


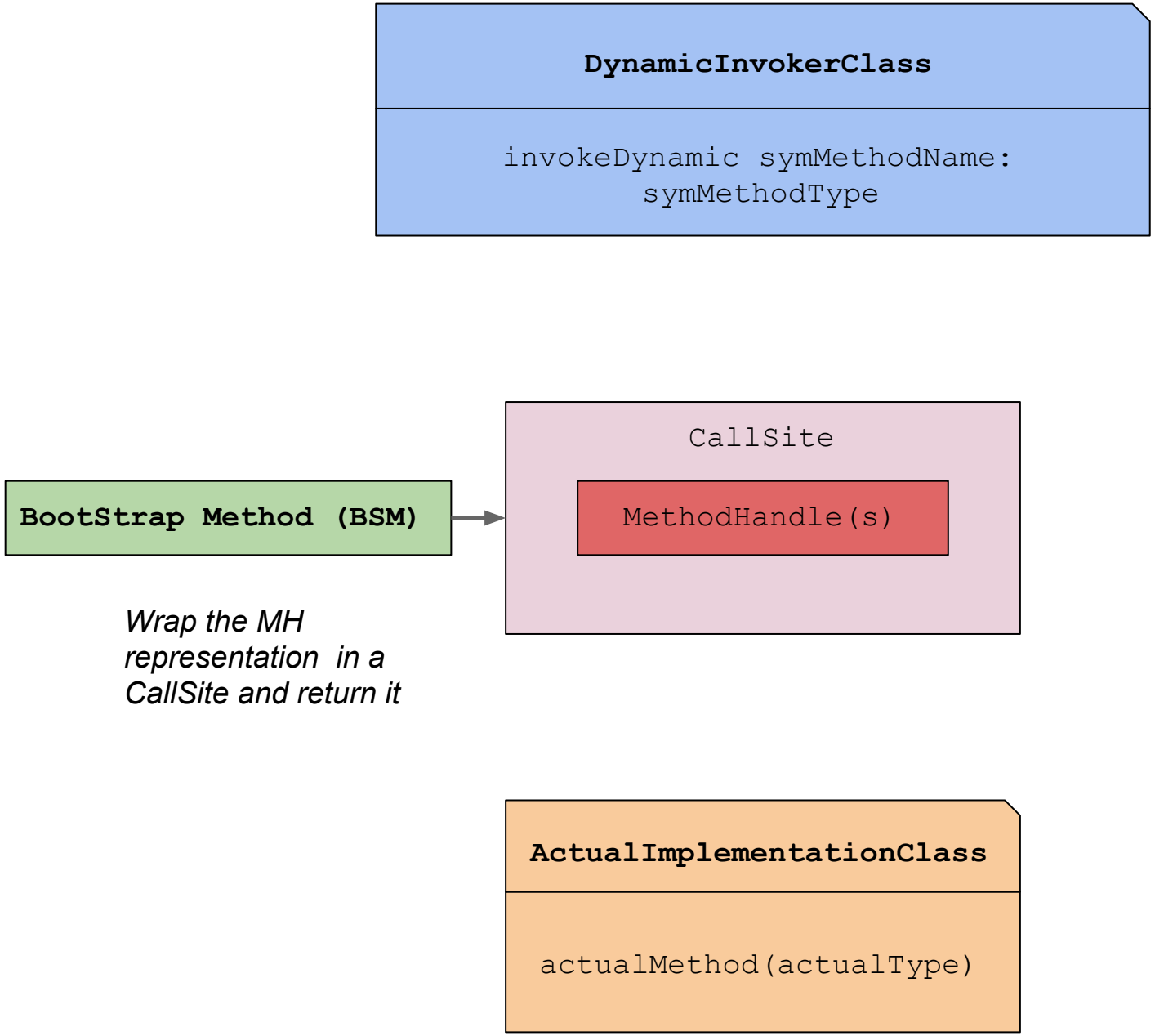

DynamicInvokerClass
invokeDynamic symMethodName:
symMethodType
How to??
ActualImplementationClass
actualMethod(actualType)

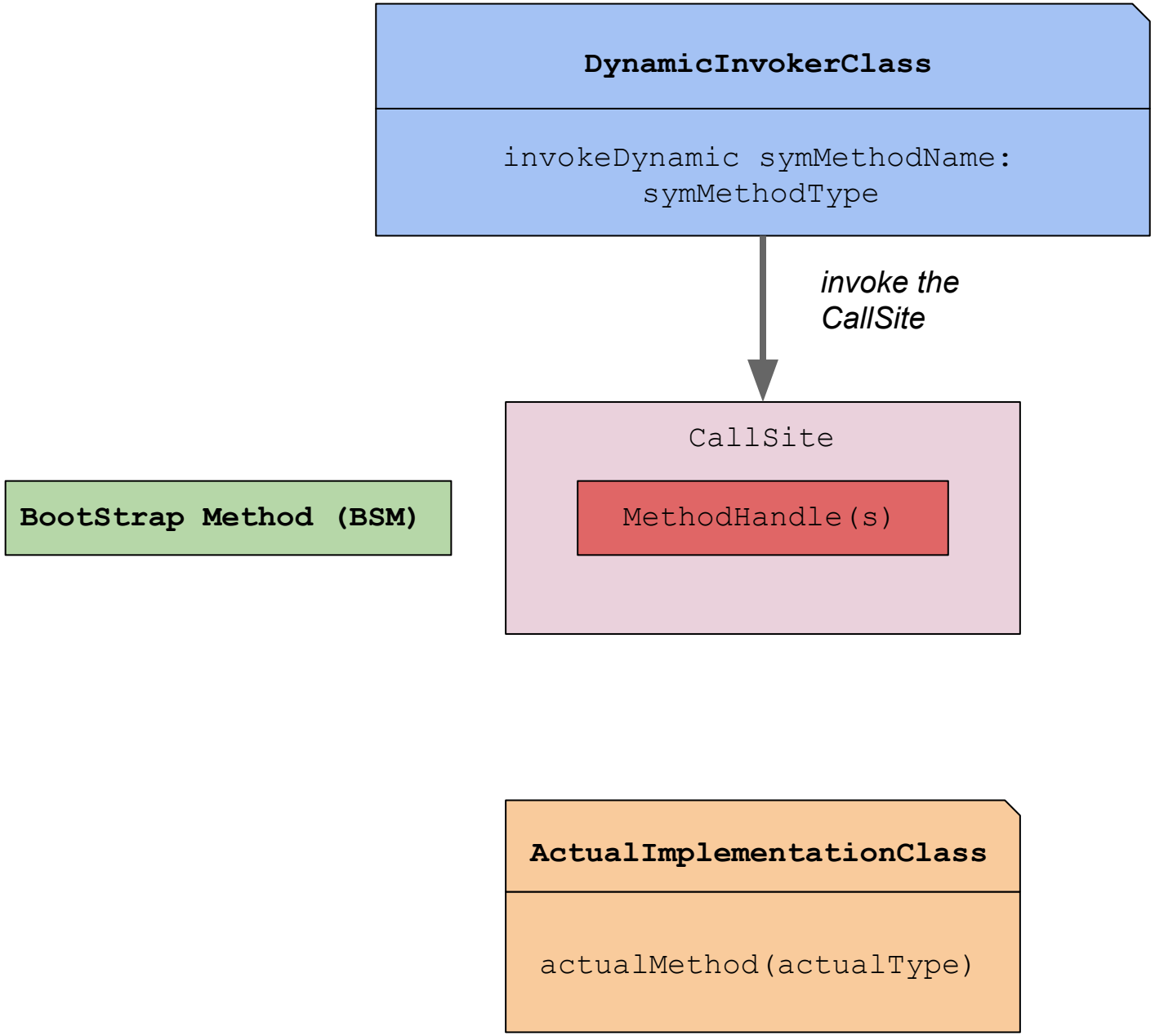
Delegation to a BootStrap Method

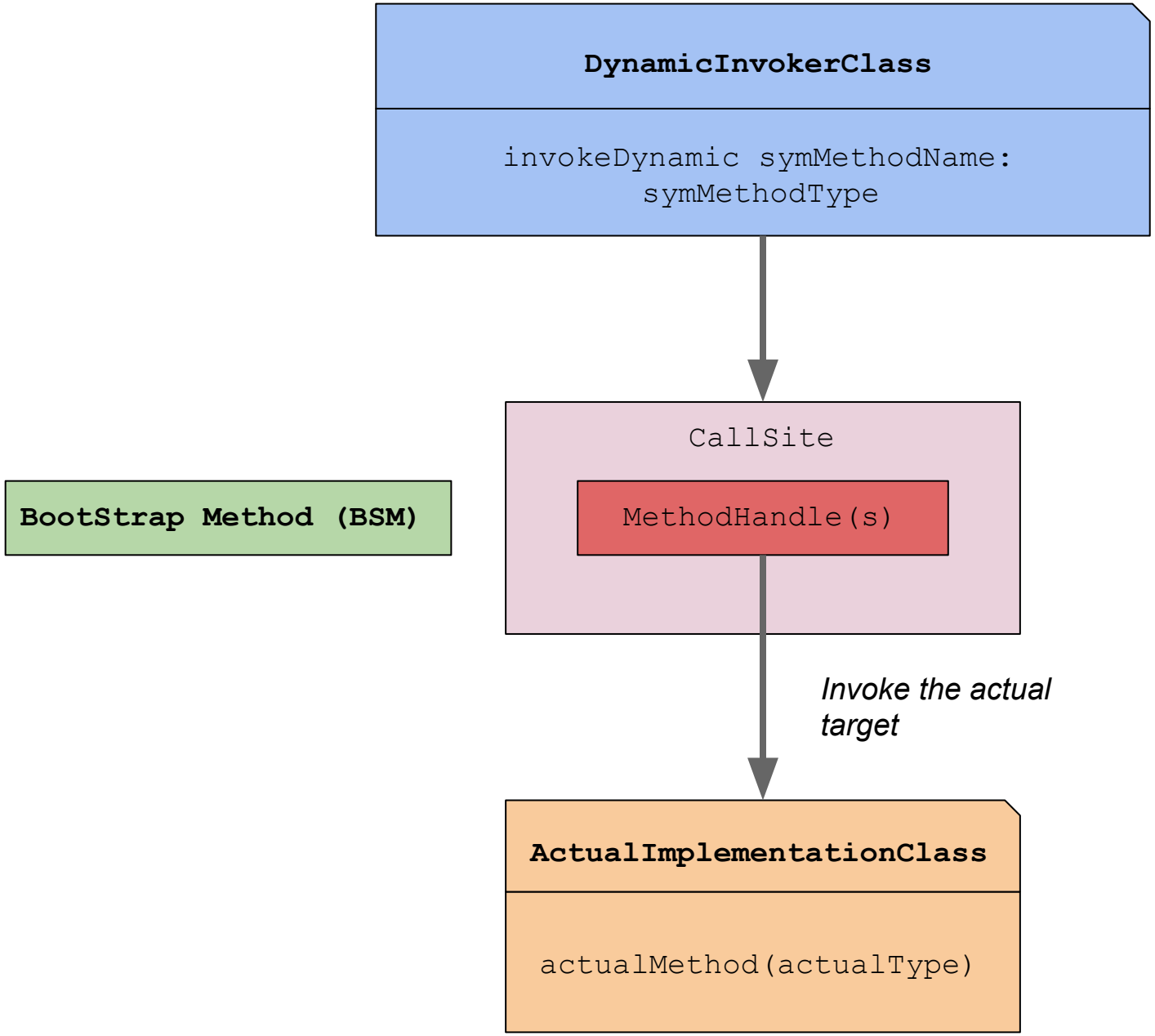

DynamicInvokerClass
invokeDynamic symMethodName:
symMethodType
Each InvokeDynamic instruction refers to a
BootStrap Method invoked the 1st time
BootStrap Method (BSM)
ActualImplementationClass
actualMethod(actualType)


DynamicInvokerClass
invokeDynamic symMethodName:
symMethodType
BootStrap Method (BSM)
lookup
ActualImplementationClass
actualMethod(actualType)


DynamicInvokerClass
invokeDynamic symMethodName:
symMethodType
BootStrap Method (BSM)
MethodHandle(s)
Compute the MH
representing the
target
ActualImplementationClass
actualMethod(actualType)


DynamicInvokerClass
invokeDynamic symMethodName:
symMethodType
CallSite
MethodHandle(s)
BootStrap Method (BSM)
Wrap the MH
representation in a
CallSite and return it
ActualImplementationClass
actualMethod(actualType)


DynamicInvokerClass
invokeDynamic symMethodName:
symMethodType
invoke the
CallSite
CallSite
MethodHandle(s)
BootStrap Method (BSM)
ActualImplementationClass
actualMethod(actualType)


DynamicInvokerClass
invokeDynamic symMethodName:
symMethodType
CallSite
MethodHandle(s)
BootStrap Method (BSM)
Invoke the actual target
ActualImplementationClass
actualMethod(actualType)

BootStrap Method needs?

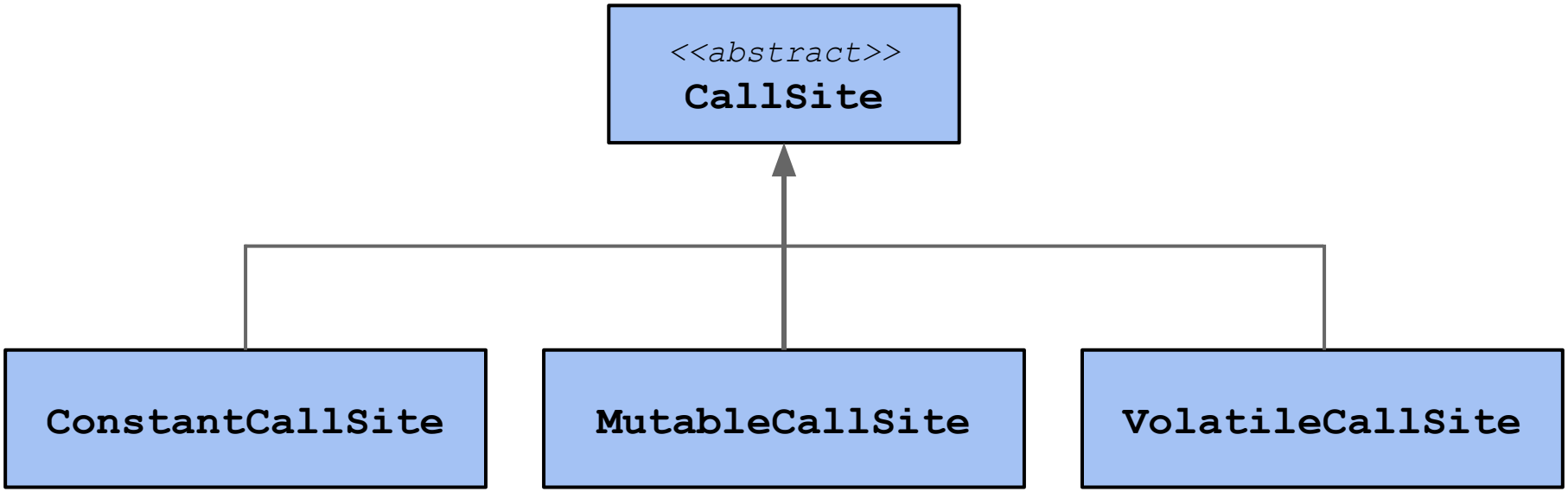
BootStrap Method needs:

The invocation context (`MethodHandles.Lookup`)
A symbolic name (`String`)
The resolved type descriptor of the call (`MethodType`)
Optional arguments (`constants`)

```java
public static CallSite bootstrap(Lookup lookup, String name, MethodType
type)
  throws Throwable {

  MethodHandle target = lookup.findStatic(MessageFormat. class, "format",
    methodType(String. class, String.class, Object[].class))
    .bindTo("Hello {0} {1}!")
    .asCollector(String[]. class, 2)
    .asType(type);

    return new ConstantCallSite(target);

}

public static void main(String[] args)  throws Throwable{
  CallSite callSite = bootstrap(
    MethodHandles.lookup(),
    "myGreeter",
    methodType(String. class, String.class, String.class)
  );

  String greet = (String) callSite.dynamicInvoker().invokeWithArguments(
    "John", "Doe"
  );

  assert greet.equals("Hello John Doe!");
}
```

The target representation

The binding between invoker & receiver at runtime


<<abstract>>
CallSite
ConstantCallSite
MutableCallSite
VolatileCallSite

Chapter III
Bytecode strikes back

How to produce `invokeDynamic` bytecode ops?

You can’t!

You can’t!

at the moment…

http://asm.ow2.org/

All together: YAAL

YAAL = **Y**et **A**nother **A**wesome **L**anguage

= ~~Makes me rich~~

= ~~Makes me famous~~

= ~~Useful~~

= Kind of `invokedynamic` how to

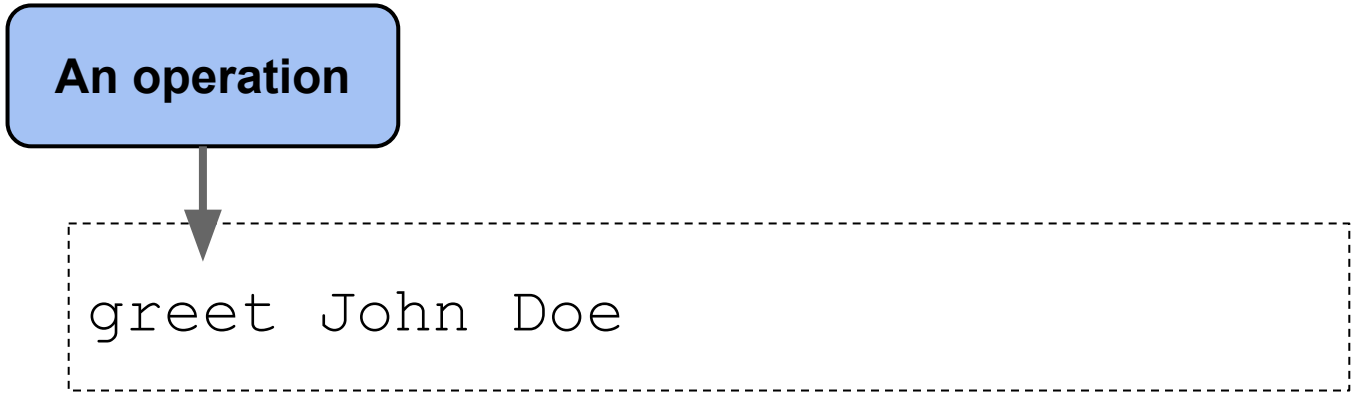
Demo time!

https://github.com/danielpetisme/pimp-my-java

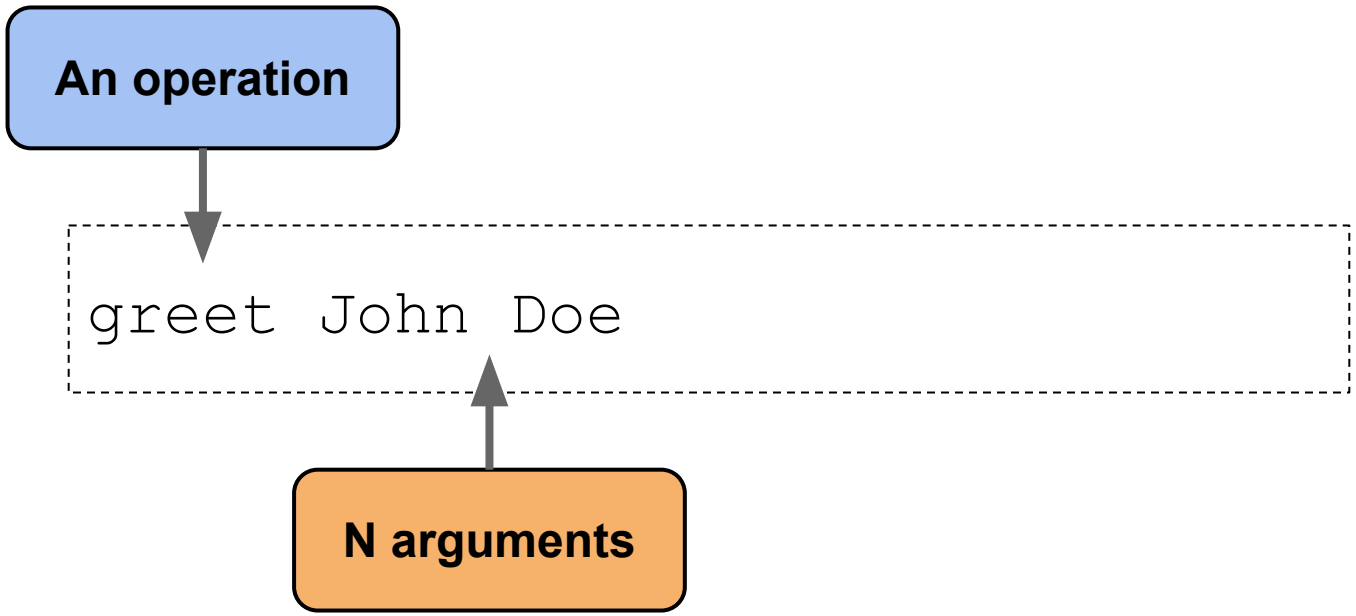

Plan A
Plan B

```
greet John Doe
```

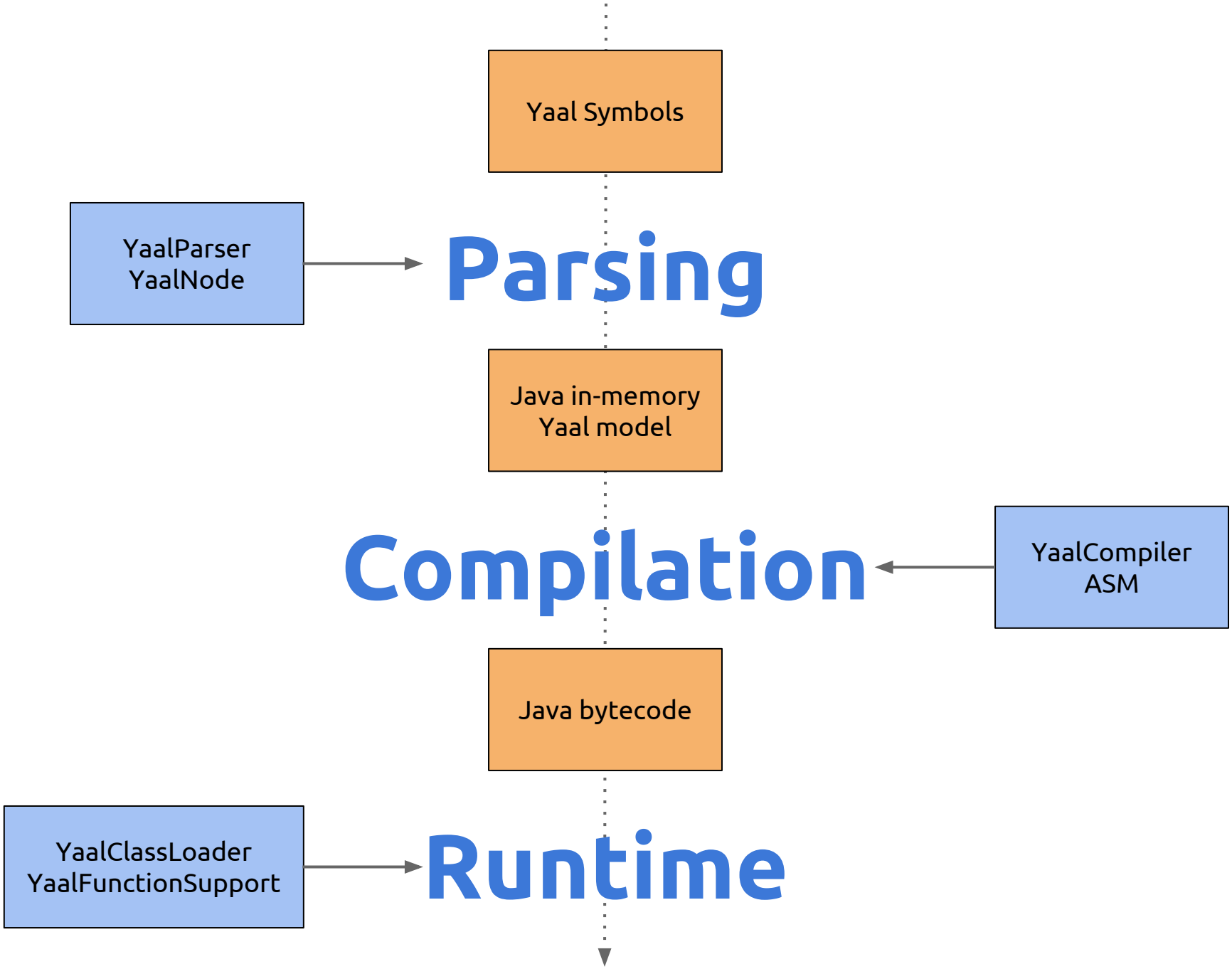
Yaal Syntax



Yaal Syntax



Yaal Syntax


Yaal Symbols
YaalParser
YaalNode
Parsing
Java in-memory
Yaal model
Compilation
YaalCompiler
ASM
Java bytecode
YaalClassLoader
YaalFunctionSupport
Runtime

```
MethodVisitor mv = writer.visitMethod(
    ACC_STATIC | ACC_PUBLIC, "main", "([Ljava/lang/String;)V", null,
null);

String bootstrapOwner =  "lavajug/yaal/runtime/YaalFunctionSupport";
String bootstrapMethod = "bootstrap";
String desc = MethodType.methodType(
  CallSite.class,
  MethodHandles.Lookup.class,
  String.class,
  MethodType.class).toMethodDescriptorString();

Handle bsm = new Handle(
  H_INVOKESTATIC,
  bootstrapOwner,
  bootstrapMethod,
  desc
);

for (YaalNode node : nodes) {
  for(String argument : node.arguments) {
    mv.visitLdcInsn(argument);
  }

  mv.visitInvokeDynamicInsn(
    node.operator,
    genericMethodType(node.arguments.length).toMethodDescriptorString(),
    bsm
  );

}
...
```

Creating a main

BSM definition

push args on the stack

Creating an `invokedynamic` instruction

YaalCompiler#compile

```
public class YaalFunctionSupport {

  public static CallSite bootstrap(
    MethodHandles.Lookup lookup, String name, MethodType type
  ) throws NoSuchMethodException, IllegalAccessException {

    Method predefinedMethod = findMethodByName(Predefined.class, name);

    MethodHandle target = lookup.unreflect(predefinedMethod).asType
(type);

    return new ConstantCallSite(target);
  }
…
}
```

unreflect a method from Yaal Predefined functions

To take away

< Java 1.7 Type checking at compilation.
Hardcoded callsites with types

Java 1.7

invoke dynamic

user-defined bytecode
Bytecode (ASM) + BootStrap

method linking & adaptation
MethodHandle

Use symbolic specifications at compilation
Defer callsite bindings to runtime

One more thing...

Thanks @jponge

Demystifying `invokedynamic`

Part I

http://www.oraclejavamagazine-digital.com/javamagazine/20130102?pg=50#pg50

Part II

http://www.oraclejavamagazine-digital.com/javamagazine/20130506?pg=42#pg42

Golo for newbies!
-> @k33g_org

https://github.com/k33g/golo-tour/tree/master/04-Golo.63.LavaJUG

You have

Questions

We may have

Answers